



# **Brief on Autonomy Initiatives in the US DoD**

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Autonomy Priority Steering Council

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# Key DOD Challenges Addressed by Autonomy



***Decentralization, Uncertainty, Complexity...Military Power in the 21<sup>st</sup> Century will be defined by our ability to *adapt* – this is *THE* hallmark of autonomy***

**Manpower efficiencies:** Insufficient manpower to support complex missions such as command and control and surveillance across relevant battlespace

**Harsh environments:** Operational environments that do not reasonably permit humans to enter and sustain activity

**New mission requirements:** Need adaptive autonomous control of vehicle systems in face of unpredictable environments and challenging missions





# DoD Science & Technology Initiatives-- Preparing for the Future



- **Operational missions with:**

- Expanded duration
- Intermittent communication disruptions
- Complex, contested, and dynamic environments/situations
- Highly populated environments
- Larger array of asset capability
  - Cross domain (air, land, sea, space, cyber)
  - Multiple autonomous systems working as a team

**Autonomy is not about making widgets...  
It is making existing/future systems more self-governing**



# What is “Automated” Technology?

*Automation: Using machines to accomplish tasks traditionally performed by humans. Automated systems are most effective in predictable environments. Automation is not limited to simple tasks, but rather to well defined tasks with predetermined responses to all operational contingencies.*



## ***Historic Challenges Associated with Automated Technology:***

### ***Technical***

*Computer processing speed  
Sensor development/integration  
Cyber/mechanical teaming*

### ***Social***

*Human trust in automation  
Impact upon work force/political  
Human-machine teaming*

### ***Economic***

*Significant initial investment/maintenance*





# What is “Autonomous” Technology?

*Autonomy: Having the capability and freedom to self-direct to achieve mission objectives. An autonomous system makes choices and has the human’s proxy for those decisions.*



## **Challenges Associated with Autonomous Technology:**

### **Technical**

*Human/Autonomous System Interaction and Collaboration  
Scalable Teaming of Autonomous Systems  
Machine Reasoning and Intelligence  
Testing and Evaluation (T&E), Verification and Validation (V&V)*

### **Social**

*Human-machine teaming  
Public perception of unmanned vehicles (land, sea, air)*

### **Economic**

*Potential game-changing opportunity for many industries, including transportation, healthcare, security*



# The Automation-Autonomy Continuum

*Primary sources of automation brittleness:*

1. *Dynamic and complex mission requirements*
2. *Dynamic and complex operational environments*

*Automation*

*Autonomy*

***In a static environment, with a static mission, automation and autonomy converge. However, in reality, where dynamic environments collide with dynamic missions, automation can only support a small fraction of autonomy requirements.***





# DoD Technology Research and Development Strategy: Establishment of 7 Priority Steering Councils (PSC)



## Complex Threats

- ➔ Electronic Warfare/Electronic Protection
- ➔ Cyber Science and Technology
- ➔ Counter Weapons of Mass Destruction

## Force Multipliers

- ➔ Data-to-Decisions
- ➔ Autonomy
- ➔ Human Systems
- ➔ Engineered Resilient Systems

Unique Synergy



# Autonomy Priority Steering Council Linkages



White House  
Office of Science  
and Technology  
Policy Robotics  
Group



COCOM USERS



Academic  
Collaborations

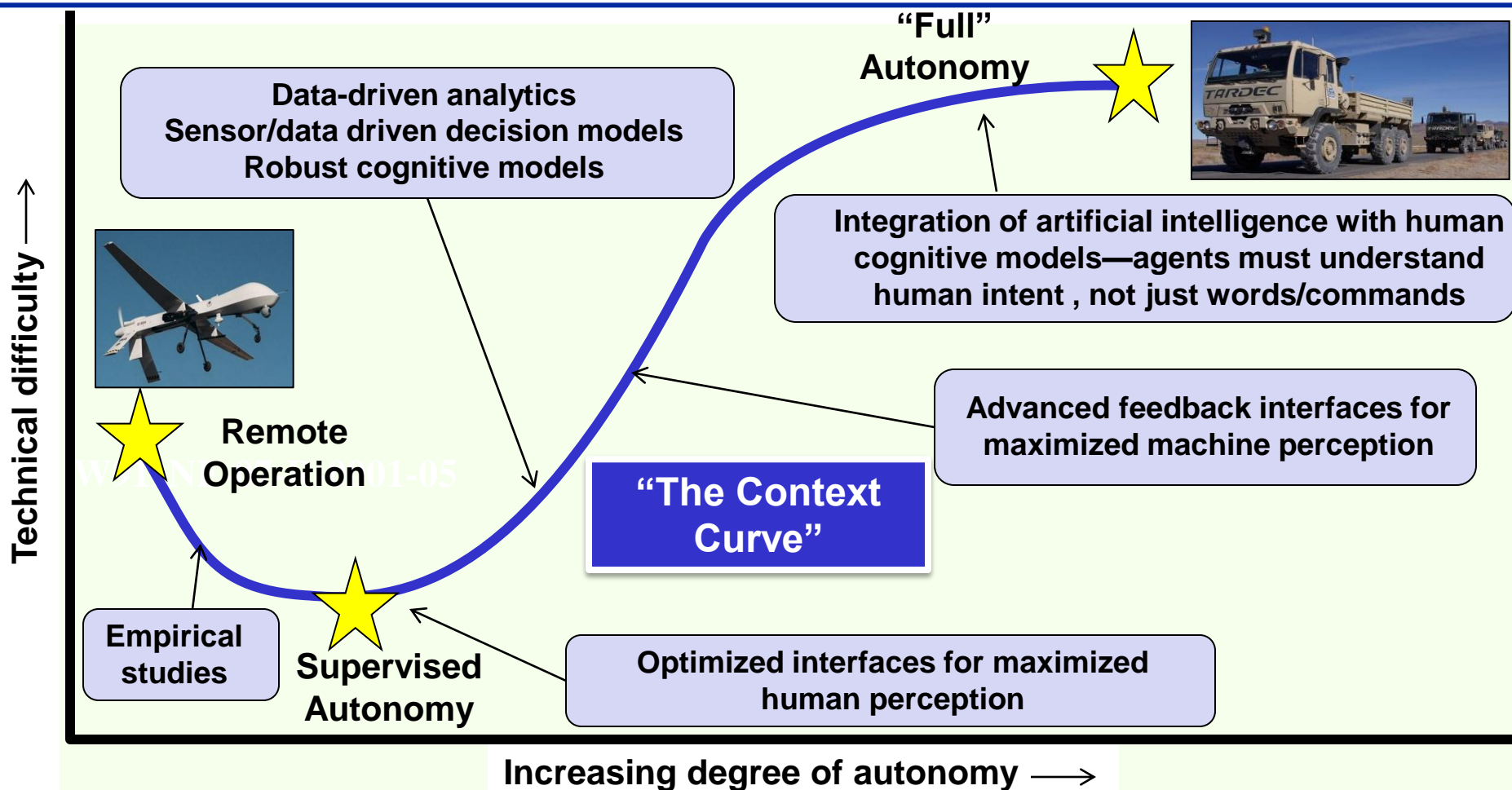


Other Federal Agencies





# Autonomy Capability Curve



**Data comprehension (that of the human and his agent) drives functionality**



# Autonomy PSC

## Technical Challenge Areas and Gaps



- **Human/Autonomous System Interaction and Collaboration**
  - *Human and machines understanding mission context, sharing understanding and situation awareness, and adapting to the needs & capabilities of another.*
- **Scalable teaming of Autonomous Systems**
  - *Self-organizing teams, initiating and completing complex mission tasks (as a team or individuals).*
- **Machine Reasoning and Intelligence**
  - *Ability to sense, perceive, plan, decide and act*
- **Test, Evaluation, Validation, and Verification**
  - *Methods & facilities to test responses and decisions to various environmental stimuli*

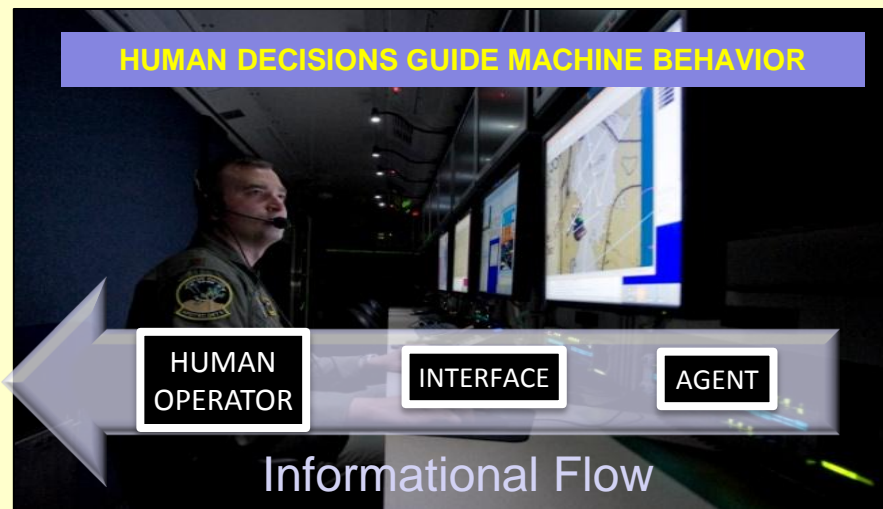


# Man-Machine Common Perception



DoD must approach autonomy as a unique human/machine or machine/machine system where decision-making is shared.

If decision-making is shared, there must be some level of shared perception.



**Current Status**



**Future Status**



# Autonomy PSC Emphasis: Advanced Test & Evaluation and Verification & Validation



## Advanced LVC Test Beds Addressing:

- Performance in Contested Environments
- Human-Agent Teaming
- Scalable Teaming of Autonomous Agents  
(Including Cross Domain)
- Machine Reasoning and Intelligence
- Computer Model and Algorithm Analysis







# Autonomy Priority Steering Council

Morley Stone, Chair



**US Air Force Research Laboratory**



**US Army--Army Research Lab and TARDEC**



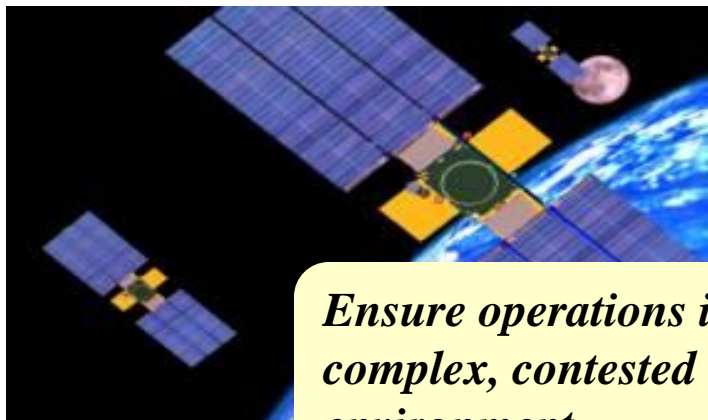
**US Navy--Office of Naval Research and Naval Research Laboratory**



**Defense Threat Reduction Agency**



# AFRL Autonomy Vision



*Ensure operations in complex, contested environment*



*Demonstrate highly effective human-machine teaming*

**Intelligent machines seamlessly integrated with humans - maximizing mission performance in complex and contested environments**

*Create actively coordinated teams of multiple machines*





# Autonomy S&T Missions Across AFRL



## Human-Automation Interaction

- Supervisory Control
- Enhanced Training
- Trust in Automation

## Autonomous Space Vehicles

- Constellation Management
- Cooperative Tactics for Dynamic Teams

## Autonomous Aerospace Systems

- Airspace Integration
- Intelligent / Adaptive Flight Control
- Cooperative Teaming
- Systems of Systems Interactions
- Verification / Validation

## Automated Sensor Data Fusion & Interpretation

- Sensor Resource Management
- Performance-Driven Sensing
- Automated Exploitation and Analysis
- Trusted Autonomous Exploitation

## Common Challenges

- Machine reasoning and intelligence
- Human/System Interaction
- Scalable Teaming
- Testing and Evaluation (T&E) and Verification and Validation (V&V)

## Autonomous Munitions

- Systems of Systems Interactions
- Verification / Validation
- Command and Control Systems
- Position, Navigation and Timing



# Principles of USAF Autonomy Human Factors Research



## One design approach: “Leftover” Principle

- Automate as much as possible: human does ‘leftover’ tasks
- Automation does what it does and human adapts

- Rigid, inflexible interaction
- Little automation transparency
- Mode confusion
- Lacks bi-directional intent understanding
- Automation complacency & bias
- Vigilance decrement
- Miscalibrated trust

## Operator-preferred approach: “User-Centered” Design



VS.







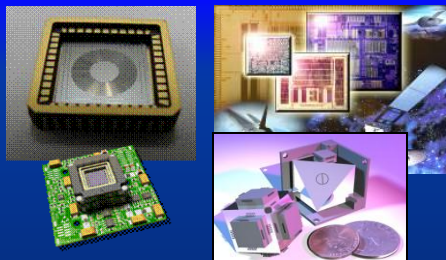
# Challenge: Precision Navigation and Timing (PNT) Sources



- Small Unmanned Air Systems may have Greater Vulnerability to GPS Jamming Due To:
  - Support of Close-in Ops
  - Unable to Support Large 'Traditional' Military GPS Equipment
- AFRL, partnered with others, is Developing Technology Solutions that:

**Decrease  
PNT SWaP**

Developing Miniature  
Anti-Jam Military GPS  
Receivers

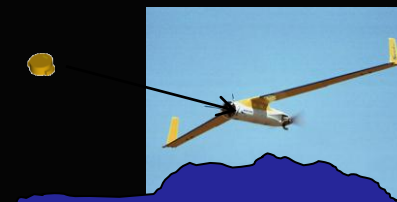


Shrinking Navigation  
Grade Gyroscopes  
(Partnered with DARPA)



Small GPS Antenna Arrays  
and Distributed Element  
Anti-Jam

**Increases PNT  
Availability**



Inertial/GPS/Sensor  
Augmentation  
(e.g. vision-aided nav)

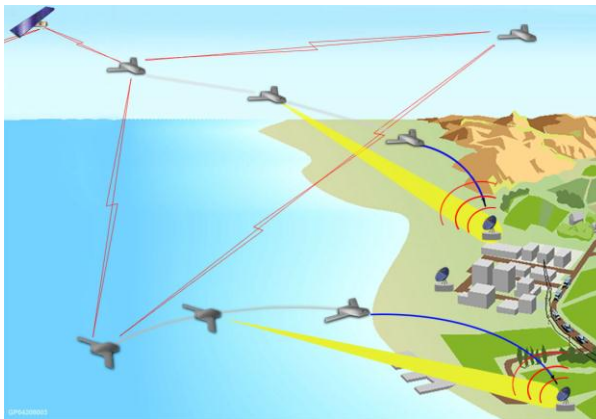


# Challenge: Cooperation & Teaming

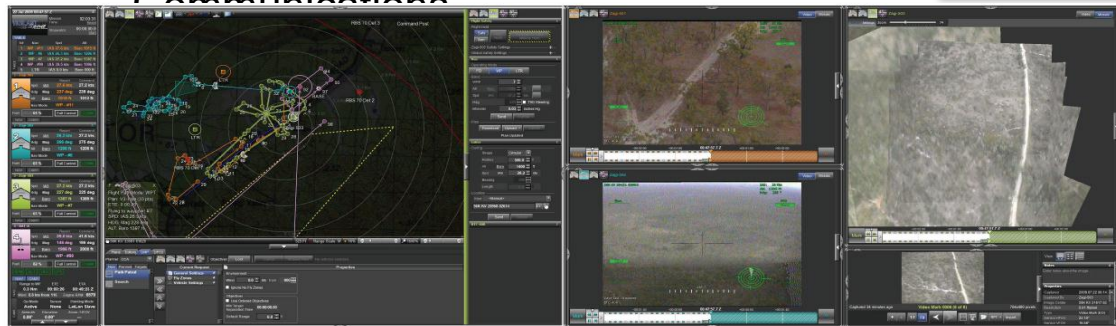


## Desired Capability:

- UAV teams working together in pursuit of common mission goals
- Ad-hoc collaboration
- Adaptation & learning
- Key sub-challenges:
  - Uncertainty
  - Coupling



Vandenberg AFB  
perimeter  
surveillance demo



Talisman Saber 2009  
Participation

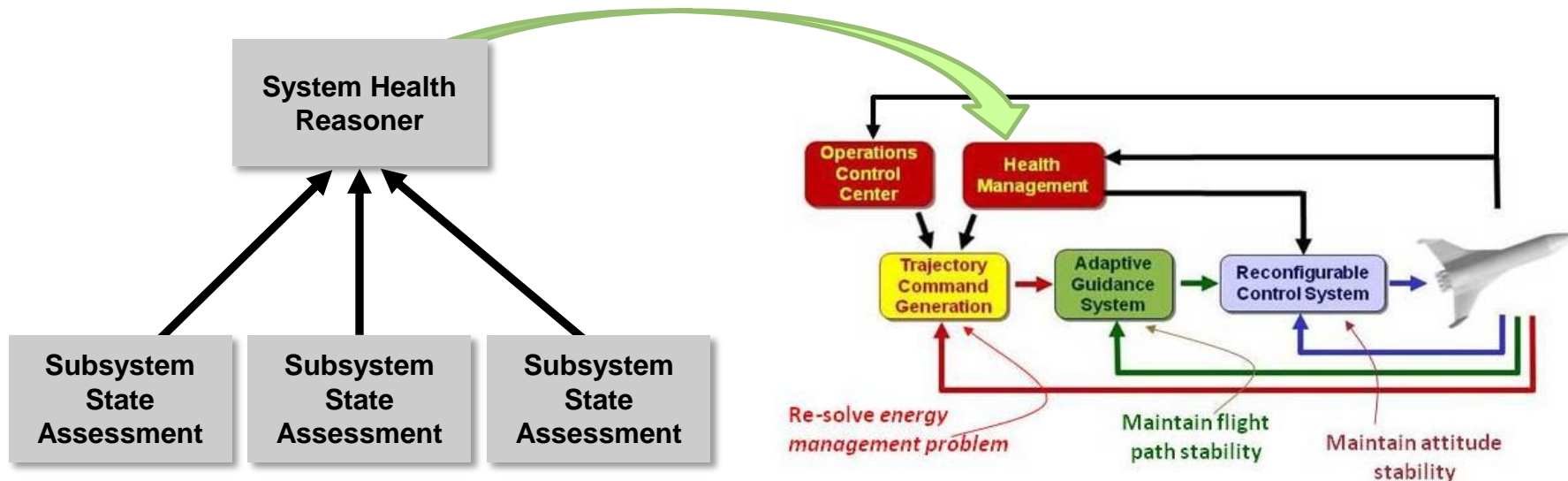
- 71 sorties, 64 flight hours, 12 days



# Challenge: Adaptation to Degradations in Systems Health

## Motivation: Autonomous Systems need to be responsive to systems health

- Determination of failure, or impending failure
- Reconfiguration of control to allow for safe recovery, or
- Adaptation to enable continued mission operations



Hierarchical health diagnosis architecture with feedback and reasoning for disambiguation

Adaptive inner-loop (stability) and outer-loop (trajectory) control to recover from failures



# Autonomy Priority Steering Council



**US Air Force Research Laboratory--Morley Stone,  
Chair**



**US Army--Army Research Lab and TARDEC**



**US Navy--Office of Naval Research and Naval  
Research Laboratory**



**Defense Threat Reduction Agency**





# US Army Ground Robotics Realities



- **Robotics benefits...**

- Robots can extend the reach of the soldier
- Robots can reduce the load of the soldier
- Robots can go into some dangerous places
- Robots are better at doing some tasks

- **The current realities of 'fielded' mobile ground robotics...**

- Robots are mostly remotely controlled or tele-operated
- Robots are difficult to control
- Robots work best in benign, structured environments
- Robots are slow and can't keep up with the operation tempo
- Robots are expensive
- Robots break down frequently
- Robots that are 'intelligent' aren't fielded because we can't guarantee their behavior under all conditions





# ***A Vision for the Army:***

## **The Robot is a Member of the Unit**

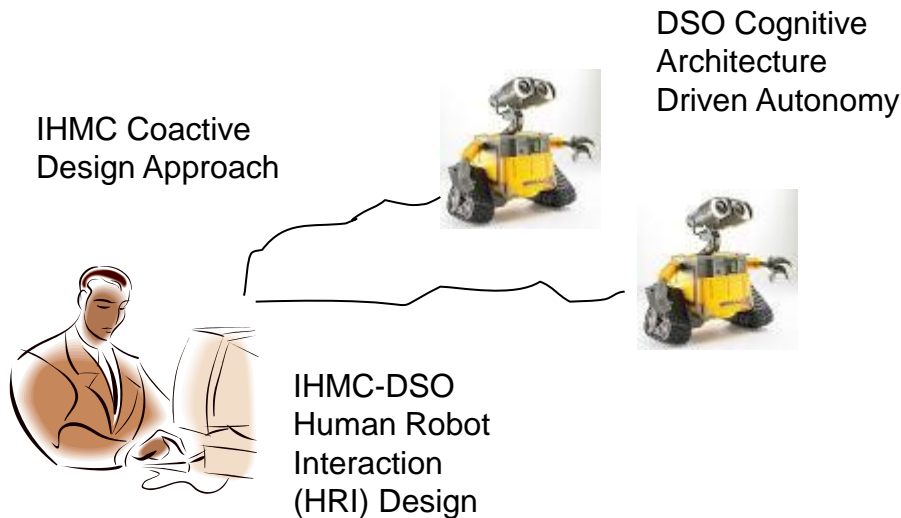
- **Understand the mission**
  - Receive and correctly interpret orders
  - React to changing situations
- **Understand the environment**
  - Recognize “rubble pile by lamppost”
  - Observe person fleeing checkpoint
  - Spot suspicious activity near intersection
- **Move in a tactically correct way**
  - Move downrange to IED – and return
  - Check intersection before manned units pass through it
  - Maintain tactical integrity moving through urban environment
- **Communicate clearly & efficiently**
  - Ask for assistance when needed
  - Report salient activity – e.g., insurgent entering building, fleeing checkpoint
- **Perform missions**
  - Monitor activity at checkpoint
  - Navigate autonomously to combat outpost
  - Inspect and neutralize IED
  - Perform ISR in urban setting



***Able to function in a world designed for humans, to grasp small objects, to open doors, to carry the wounded, etc.***

# DSO-IHMC: Human-Robot Peering System for Challenging Surveillance Missions

Objective : Develop a system to improve performance of a team, composed of a human and two robotics platforms, during a challenging surveillance mission



## Proposed R&D Approach

1. Employ IHMC's Coactive Design Approach to study how human and robots can work together during surveillance missions.
2. Robot's autonomy driven by DSO Cognitive Architecture with the ability to adapt and learn from human input.
3. HRI design that support mission interdependence between human and robots and leverages advanced interface concepts, such as exploiting both focal and ambient vision to enable human multi-tasking (e.g. Joint IHMC-DSO patent on Ambient Obstacle Avoidance)

Example Scenario – Robot perceptual imitations prevent classification of an object. Human participation not only enables correct classification, but the DSO CA also learns from this assistance and the learned knowledge will improve future autonomous perception.

## What We will Achieve ?

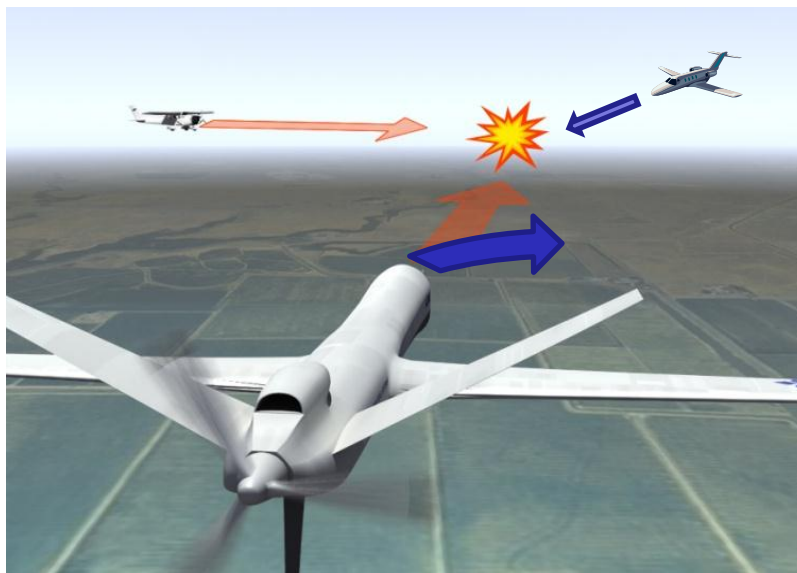
Improved partnering of the human and robots through better support for interdependence in surveillance missions. The human will supplement robot autonomy to reduce robot frailty and the automation and interfaces will be designed to leverage unique human capabilities to be brought to bare on the surveillance mission. Improved partnering will result in a more effective human-robot team.

## Next Steps

1. To jointly work out a detailed proposal by Mar 2013 for funding consideration.



# Questions/Comments?



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